Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary Information

Anomalous Behavior of Nearly-Entire Visible Band Manipulated with Degenerated Image Dipole Array

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1. Charge distribution

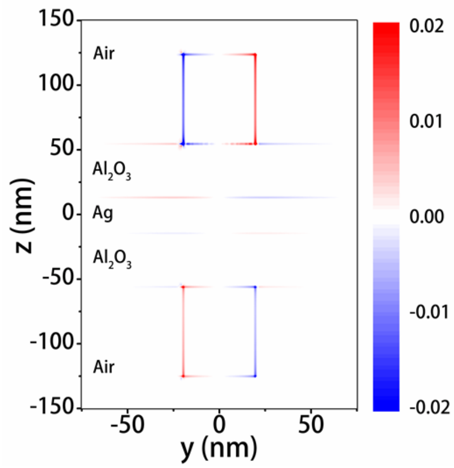

Fig. S1 Charge distribution of one-dimensional nanowire at wavelength λ = 700 nm, which supports transmittance as red dashed line shown in Fig. 2d in the main text. It is obvious that dipoles exist on the top and at the bottom. Here h = 20 nm, d= 30 nm. t = 50 nm and p_y = 150 nm. $L_1 = L_2$ = 40 nm.

2. Factors of affecting the bending performance

In order to estimate the phase delay, linear polarized light is normally incident on one-dimensional nanowire array, as shown in Fig. S2a. By enlarging the period of nanowire along y-axis from $p_y = 150$ nm to 200 nm, larger tunable range of phase is possible with the proposed structure. Coverage of 2π phase delay can even be achieved at $\lambda = 600$ nm with $p_y = 200$ nm as shown in Fig. S3b. We therefore simulate the bending performance of the structure with $p_y = 200$ nm, $L_1 = 10$ nm and $L_2 = 140$ nm, which is supposed to support phase delay covering 2π range at $\lambda = 600$ nm. As shown in Fig. S3a, the wavefront of structure is even worse than that supported by structure with $p_y = 150$ nm in the main text. However, the planar feature retains well at $\lambda = 700$ nm. The main reason can be attributed to the interference between the normal and anomalous transmitted lights. As shown in Fig. S4a, despite of the expected anomalous light, i.e. +1 order, there are energies being distributed to other unexpected orders. For instance, even though the anomalous transmission efficiency is as high as 23% at $\lambda = 600$ nm, there is 14% energy propagating along the normal direction for structure with $p_y = 200$ nm. We therefore calculated field distribution of two plane waves. One propagates normally downward with $E_0 = A_0 \exp\left(ik_0 z\right)$, which corresponds to 0 order, and the other $E_{+1} = A_{+1} \exp\left(i\left(k_0 \sin\theta_{+1} \cdot x + k_0 \cos\theta_{+1} \cdot z\right)\right)$, where θ_{+} is set as 30° for +1 order (i.e., the anomalous light). A_0 and A_{+1} are amplitudes, which can be estimated from Fig. S5. For structure with $p_y = 200$ nm, $A_0 = 0.37$ and $A_{+1} = 0.48$ at $\lambda = 600$ nm. The little difference in transmitted amplitude will definitely lead to an obvious interference. As a result, the planar feature gets hard to define. In contrast, for structure with $p_y = 150$ nm, $A_0 = 0.06$ and $A_{+1} = 0.54$. Therefore, the planar feature can be well defined as shown in Fig. S5b. Therefore, one may notice that, although 2π phase delay coverage or a constant phase gradient is beneficial for retaining planar feature in anomalous bent wave, it is more important to get rid of other diffraction orders totally. It can also be verified by the field distribution at $\lambda = 700$ nm, as shown in Fig. S3b. Well-defined wavefront for both refracted and reflected light originates from suppression of other unexpected diffraction order.

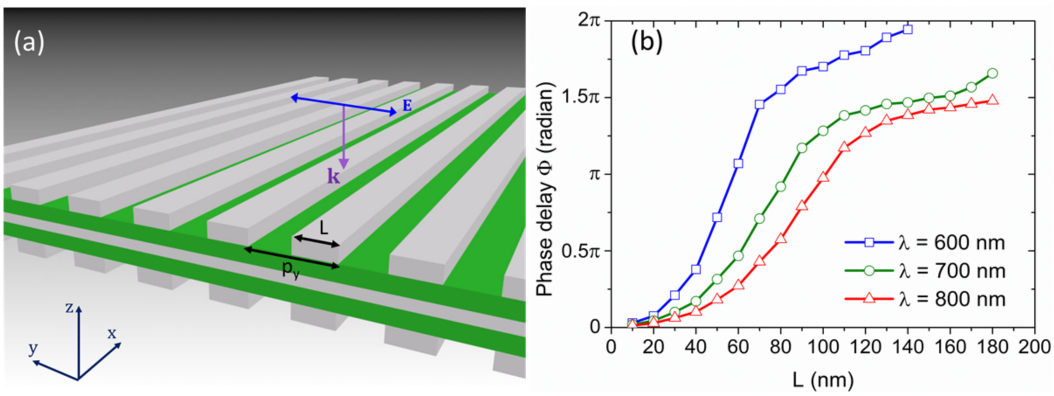

Fig. S2 (a) Schematic structure of one-dimensional nanowire for phase delay estimation and (b) phase delay Φ of refracted light versus width of one-dimensional nanowire at wavelength $\lambda = 600$ nm, 700 nm and 800nm. Here h = 20 nm, d = 30 nm, t = 50 nm and p_y = 200 nm. $L_1 = L_2 = L$ ranges from 10 nm to 180 nm.

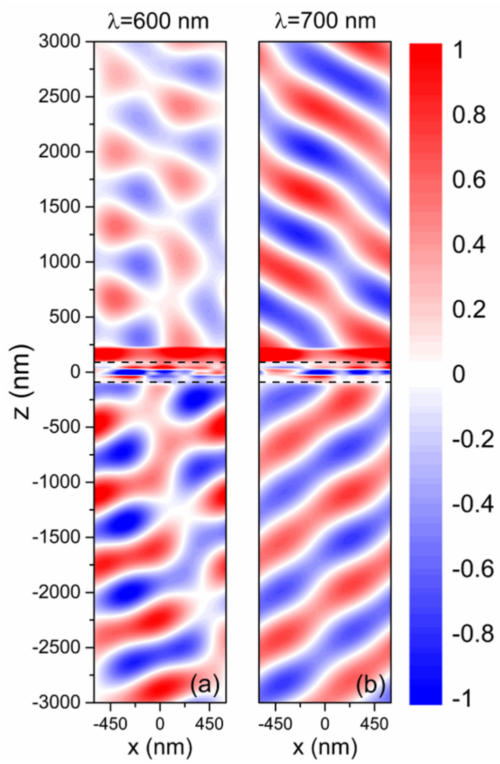

Fig. S3 Electric field distributions of Ey component at wavelength (a) 600 nm and (b) 700 nm of structure supporting phase delay coverage 2π with p_y = 200 nm, L_1= 10 nm and L_2 = 140 nm. All the simulations are performed at normal incidence. Other parameters are h = 20 nm, d = 30 nm, t = 50 nm and p_x = 1200 nm.

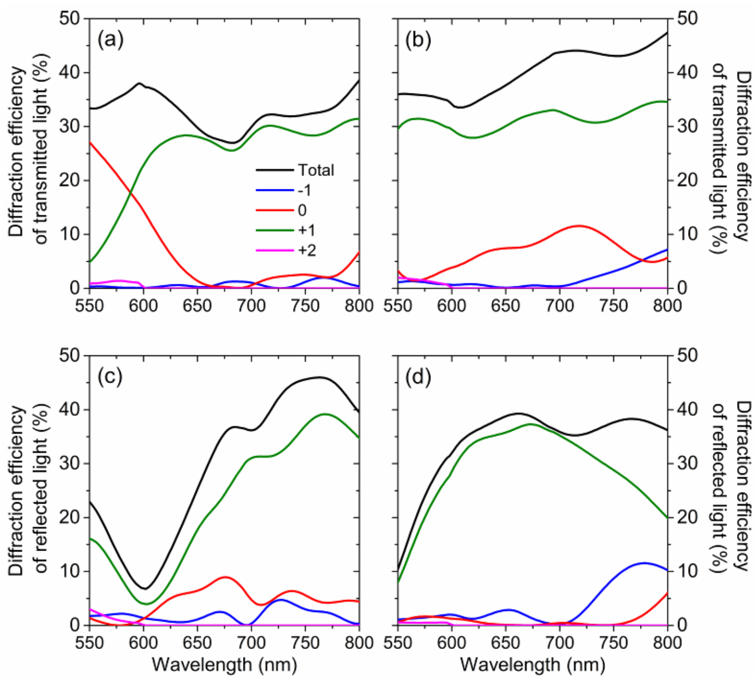

Fig. S4 Diffraction efficiency of transmitted (a) and (b) and reflected (c) and (d) energies against wavelength. (a) and (c) are calculated with p_y = 200 nm while (b) and (d) are calculated with p_y = 150 nm.

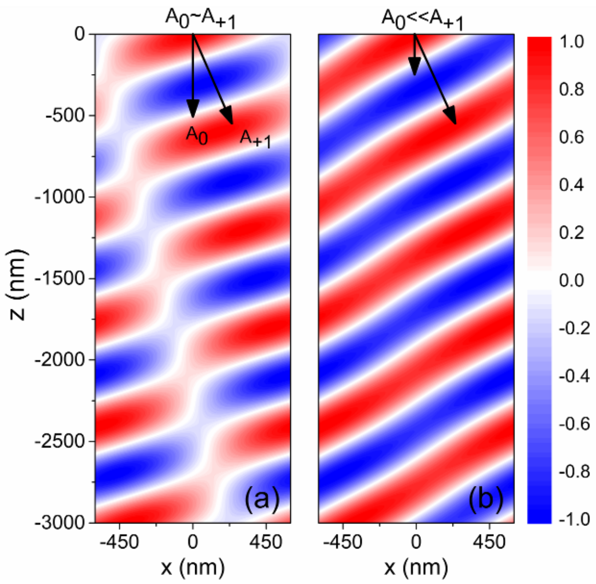

Fig. S5 Interference of 0 and +1 order (anomalous light) for two cases similar to (a) p_y = 200 nm. A_0 = 0.37 and A_{+1} = 0.48 and (b) p_y = 150 nm, A_0 = 0.06 and A_{+1} = 0.54.

3. Phase delay by varying the thickness of Al_2O_3 layer

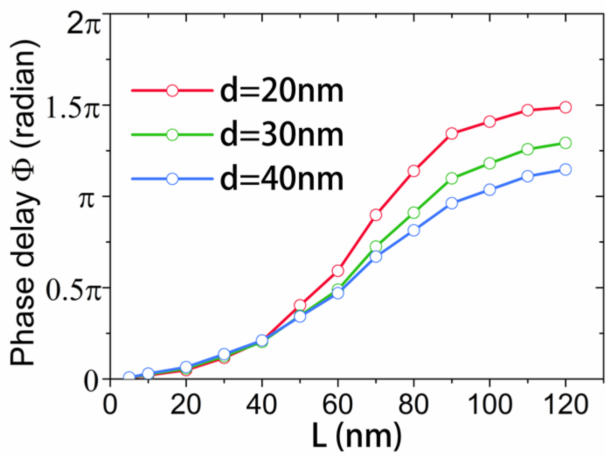

Fig. S6 Phase delay Φ of refracted light versus width of one-dimensional nanowire at wavelength λ = 700 nm. Here h = 20 nm, t = 50 nm and p_y = 150 nm. $L_1 = L_2$ = L ranges from 5 nm to 120 nm.